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Growth correlations in five species of deciduous trees

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The *Butler University Botanical Studies* journal was published by the Botany Department of Butler University, Indianapolis, Indiana, from 1929 to 1964. The scientific journal featured original papers primarily on plant ecology, taxonomy, and microbiology. The papers contain valuable historical studies, especially floristic surveys that document Indiana's vegetation in past decades. Authors were Butler faculty, current and former master's degree students and undergraduates, and other Indiana botanists. The journal was started by Stanley Cain, noted conservation biologist, and edited through most of its years of production by Ray C. Friesner, Butler's first botanist and founder of the department in 1919. The journal was distributed to learned societies and libraries through exchange.

During the years of the journal's publication, the Butler University Botany Department had an active program of research and student training. 201 bachelor's degrees and 75 master's degrees in Botany were conferred during this period. Thirty-five of these graduates went on to earn doctorates at other institutions.

The Botany Department attracted many notable faculty members and students. Distinguished faculty, in addition to Cain and Friesner , included John E. Potzger, a forest ecologist and palynologist, Willard Nelson Clute, co-founder of the American Fern Society, Marion T. Hall, former director of the Morton Arboretum, C. Mervin Palmer, Rex Webster, and John Pelton. Some of the former undergraduate and master's students who made active contributions to the fields of botany and ecology include Dwight. W. Billings, Fay Kenoyer Daily, William A. Daily, Rexford Daudenmire, Francis Hueber, Frank McCormick, Scott McCoy, Robert Petty, Potzger, Helene Starcs, and Theodore Sperry. Cain, Daubenmire, Potzger, and Billings served as Presidents of the Ecological Society of America.

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GROWTH CORRELATIONS IN FIVE SPECIES OF DECIDUOUS TREES[1]

By CHARLES W. REIMER

Since the beginning of the present century much work has been done in America on tree growth, the greatest part of this being centered around growth exhibited by coniferous species. The literature is less extensive on growth studies of deciduous trees. MacDougal's work on radial growth with the dendrometer and dendrograph (27, 28) is too extensive for review in a paper of this type. Glock (19) has given excellent review of results from study of annular rings. Dendrometer studies on deciduous trees in the midwest have been carried out by Beilmann (2), Friesner (12, 14), and Lodewick (26). Recently Daubenmire and Peters (8) using a new type of dendrometer (7) have presented the results of comparative studies of coniferous and deciduous species in Idaho. Most of the radial growth studies has consisted of ring counting (3) (5) (6) (9) (10) (13) (18) (19) (29).

Axial growth behavior during individual growth periods has been studied in a number of genera. Kienholz (23) has shown that trees may be divided into two groups from the standpoint of duration of axial growth, viz., short season trees, in which 90% of the axial growth occurs in 30 days and the total period approximates 60 to 70 days; and long season trees, in which 90% of the axial growth occurs in 60 days and the total period approximates 110 days. *Fraxinus americana, Fagus grandifolia* and *Acer saccharum* are placed in the short season group and *Betula alba, B. populifolia, Liriodendron tulipifera* and *Acer rubrum* belong to the long season group. Friesner (15, 16) has shown that *Pinus resinosa, P. strobus, P. banksiana* and *P. sylvestris* belong to the short season group. Baldwin (1), Cook (5) and Kienholz (23) have shown that *P. resinosa* belongs to the short season group.

[1] A portion of a thesis submitted in partial fulfillment of the requirements for the Master of Arts degree in the Division of Graduate Instruction, Butler University.

Pearson (31) found closest correlation between height growth of western yellow pine and spring rainfall, in Arizona. Cook (6) found that rainfall does not effect axial growth except in case of droughts. Hawley (21) found that axial growth in *Juniperus virginiana* showed closest correlation with rainfall of the preceding fall and winter months. Baldwin (1) found that temperature seemed to be the most important climatic factor in determining the beginning and rapidity of height growth. Cook (6) points out, however, that temperature is not of major importance after the early course of growth.

Friesner places the time for initiation of axial growth in four species of pine in Brown County, Indiana, as April 13 (1941). Baldwin shows much height growth beginning in April in conifers studied. Kienholz (23) says that in 1937 the time of bursting of leaf buds in nineteen hardwood and softwood species varied from April 20 to May 12; in 1938, from April 21 to May 2: and in 1939, from May 1 to May 12.

In most species studied the general sequence was: first bud activity, and then trunk activity. Friesner finds that cambial activity in the trunk of *Fagus grandifolia* and *Acer saccharum* at a height of about 4.5 feet begins at about the time when leaves are full size. As a general statement it might be said that axial growth precedes radial growth in deciduous trees (except *Fraxinus, Ulmus,* and *Quercus*) more so than in coniferous species where it oftentimes is the reverse.

Some dates of inception of radial growth in deciduous trees have been given by various authors:

Quercus	April 10	Beilmann (2)
Q. alba	April 21	Friesner (14)
Fagus sylvatica	Last half April	Kienholz (23)
	Late May to early June	MacDougal (27)
F. grandifolia	May 12	Friesner (14)
Acer negundo	May 19	Korstian (30)
A. saccharum	May 12	Friesner (25)
A. saccharinum	April 20, 27	Hanson and Brenke (20)
Ulmus fulva	April 21	Friesner (14)
U. Americana	April 21	Friesner (14)

Ring porous trees are said to demonstrate much earlier inception of growth than diffuse porous trees. Friesner (15) reported earlier inception of growth in Ulmus and Quercus (ring porous species) over Fagus and Acer (diffuse porous species). This would seem to

agree with Hubers' (22) conclusion that "Die Wasserleitung ringporiger Gehölze geht fast ausschlieszlich in aüsersten Jahresring vor sich, erfolgt aber dafur etwa zehnmal rascher als bei den auf breiter Flache leitenden zerstreutporigen Geholzen." This would indicate that because of a more rapid rate of translocation of water in ring porous wood there would be an earlier inception of growth. A recent study by Daubenmire and Peters (8) casts some doubt as to the significance of this. They found in Ulmus and Quercus which are ring porous an almost identical inception date with Fagus which is diffuse porous. This was in an area where these trees had been introduced. It, apparently, does not hold in Indiana where they are native. Juglans which is semi-ring porous instead of beginning intermediately came later than any of the other trees. The trees studied while out of their native habitat were under identical environmental conditions.

Cessation of axial growth varies with the species studied and definite correlations have been few. Some authors find a period of dragging activity in late summer, then a final and complete stoppage of elongation. Sometimes there follows a period of post-seasonal growth in which elongation of a few millimetres is noticed.

The length of shoot growth has been attributed by Kirkwood (24) to be dependent upon the size, vigor and amount of nutritive substance stored in the terminal bud during the last season. This is an agreement with rainfall correlations for the storage season indicated by Motley (30).

Radial growth in most cases is over a longer period than axial growth. For example, Hanson and Brenke (23) gave the overall radial growth period for *Acer saccharinum* as 170-177 days inclusive. MacDougal found the duration of radial growth in *Pinus flexilis* to be 61 days. *Ulmus fulva* exhibited a radial growth season of 133 days (27); Pinus and Picea, 50 to 60 days; Tsuga, 85 days; Larix, 100 days.

Friesner (17) describes radial growth as either 1) grand period curve type or essentially so (e.g., *Fagus grandifolia*), or no resemblance to the grand period type (e.g., *Ulmus americana*). One statement from this paper, "environmental controls the quantitative but not the qualitative aspects of the behavior," describes what other papers collectively have shown.

METHODS

Five species of deciduous trees were selected for this study. They are: *Fagus grandifolia, Prunus serotina, Acer saccharum, Acer platanoides,* and *Tilia americana.* The study was carried out in two plots, the Friesner area in Brendonwood, and the Voight area. The former is located about two miles west of Ft. Harrison in the northeastern section of Marion County. The latter is located on West 10th Street and about three miles from the Marion-Hendricks County line. Four dendrometers were set up in the Brendonwood area. One each was attached to the trunks of *Tilia americana, Prunus serotina, Acer saccharum* and *Acer platanoides.* The data for the fifth species was taken from a study on the estate of Charles J. Lynn being carried out by Dr. R. C. Friesner on *Fagus grandifolia.* The dendrometers were attached to the trees at breast height by metal clamps anchored deeply into the heartwood to prevent possible miscalculations from cambial growth. A cross bar was attached to these clamps and on it the dendrometers were attached. The graduations recordable made it possible to detect an increase or decrease of .01 mm. The recording arm was set in a smoothed pit shallowed in the outer bark. Care was taken not to injure the bark cambium. Readings were taken once a week. Whenever possible the readings were taken about the same time of day so as to avoid possible inaccuracy due to daily reversible changes. The clamps holding the dendrometers were made of soft rolled steel whose coefficient of linear expansion is .0000063 in. per degree Fahrenheit. The instrument itself was made entirely of metal alloys which carry a very low coefficient of expansion.

Measurements of axial elongation were made in both areas. One hundred twigs were tagged in the Brendonwood area which will be designated as Area A. Fifty twigs were tagged in the 10th Street area which will be designated as Area B.

Weekly measurements were made with a ruler graduated in millimetres. The first few weeks measurements were taken from the base point of measurement to the tip of the swelling bud. When the bud opened it became necessary to choose another point of measurement. Thus the blank species in table II indicate the week during which no accurate measurement could be taken. The measurements after opening of the leaf bud were taken to the farthest advancing evident node. This was the most stable point for measurement and represents the

closest definite area to the meristematic region. Measurements were made and recorded in both plots on the same day. A total of 4 trees of *Prunus serotina,* 2 of *Acer platanoides,* 4 of *A. saccharum,* 2 of *Tilia americana* and 5 of *Fagus grandifolia* were used for the axial measurements. Rainfall was measured weekly in each plot using a rain gauge of the United States Weather Bureau type.

In addition, rainfall data figures were taken from the United States Weather Bureau reports from stations in Marion County to see to what degree there was agreement between official data and that gathered at the point of experimentation. Data were assembled from the Holiday Park station which is located about 6 miles west of Area A, from the Weir Cook Airport station which is about 4 miles south of the West 10th Street area, and from official evaporation and temperature figures from the Climatological Data published by the U. S. Department of Commerce, Weather Bureau. These figures were averaged into weekly groups.

OBSERVATIONS AND RESULTS

The trees of area A were located in a rather level section with a fair degree of drainage. Trees 4a, 4b, 4c, 5a, and 5b were situated at the edge of an old cut (east-west) which drained the immediate area. The crown was open in most places.

Trees of area B were in an open-crowned section with good drainage. The drainage consisted of two folds of land 2-6 ft. deep. The whole area B was on a slightly higher plot of ground and would probably represent a slightly better drained and aerated section.

PRUNUS SEROTINA

Radial increase (table I) which can be interpreted as growth began on May 26, 1947 and continued until September 30. Previous to this time there were recorded alternate increases and decreases in diameter. At no time up to April 26, 1948 does the reading of total increase exceed that of the peak reached in September 1947. A total of 2.88 mm of radial enlargement were recorded for the 1947 growing season. The peak of rate of radial increase was recorded June 4. A second peak was recorded June 30. The rate was high during the entire month of June.

Axial enlargement was first evident on April 14 in numbers 81-85. After about 2 weeks of smaller increases the axial measurements on May 5 showed a great increase (table II). The figures for April 21 represent transition figures and so were omitted from the calculations. It was during this period that the terminal measuring point was changed from bud end to the farthest advancing node. Over 90% of the total elongation occurred between April 14 and June 4. The zero point was reached during the week ending June 4, no elongation being recorded for the week ending June 9. Some elongation occurred after that date in these but this was very small and the total elongation after this date did not exceed the length of the bud. After the zero point was reached in June, readings were taken with decreasing frequency. By May 5 the leaves of Prunus were between 1/2 and 3/4 full size. Axial enlargement in area A extended over a period of 8 weeks, beginning with the week ending April 14 and continuing until the week ending June 4. Radial enlargement extended over a period of 19 weeks from May 26 to September 30.

The axial growth in Prunus located in area B showed a somewhat different course of development. The initial measurements were made on these on April 14 and the first recording on April 21 just at the time of transition explained earlier. The peak of growth came during the week ending May 26. The period required for 90% of the growth was from April 21 to July 21. Not until a last check in November was there no further elongation recorded for Nos. 111-115. The peak of growth was also reached about 2 weeks after that found as the peak in trees of Area A. Twigs 141-150 also exhibited a longer period of elongation but by September they had practically reached the zero point (table II). On July 7 it was evident that next year's buds were being formed in all species studied in area B.

Acer platanoides

Inception of radial enlargement began during the week ending June 17, about 15 days later than in Prunus. The peak in rate of enlargement came during the week ending June 30 with a second peak during the week ending July 28. Radial enlargement ceased on August 4. After this time until October 20 there were recorded weekly gains and losses of varying amounts none of which ever resulted in a total radius greater than that reached on August 4. On

October 20 the dendrometer was broken and not attached again until November 24, 1947.

Axial elongation was first in evidence the week ending April 7. Measurements were to the bud tip until the week ending April 28 at which time the farthest advancing node was taken as a measuring point. The amount of growth in this species was not very great as compared with Prunus. A sharp drop in elongation was noted for the week ending May 12. This shows up to a certain extent in Prunus 1a-5a, 11a-15a. This was a week in which very little rainfall was recorded (table III), the temperature also showing a definite drop (frost being reported for two days of this week). Evaporation was relatively high (table III).

The zero point in elongation came on the week ending May 26 with only slight amounts of elongation during the following weeks. Total axial elongation up until the mid-summer zero point was over a period of 8 weeks. Total radial enlargement was over a period of 8 weeks beginning the week ending June 17 and ceasing after the week ending August 4. Total radial increase was 1.42 mm.

Acer saccharum

Radial growth in this species began during the week ending June 10, 1947. The enlargement continued until the week of August 25, a duration of 12 weeks. After August 25 the same behavior of gains and losses as found in other species is in evidence. Up to the present writing (May 10, 1948) the radius had not reached the measurement taken at the highest peak found for 1947 which indicates that radial growth had not yet started for 1948. The peak of radial growth rate was reached June 17, 1947. Two minor peaks were also recorded, one on June 30 and the other on July 14.

Axial increase in area A began April 14. In area B measurements were not taken early enough to determine exact time of begining of elongation. In area B the mid-summer zero point was reached June 4. If it were permissible to use time of elongation in area A and time of mid-summer zero point in area B, it could be said that the time of axial elongation up to the mid-summer zero point was 7 weeks, which was shorter than in either Prunus or Acer platanoides. The radial enlargement period extended 11 weeks. This is a shorter period of time for radial enlargement than was exhibited by Prunus and a longer period than was exhibited by *Acer platanoides*.

After the June 4 readings were recorded, all branches except No. 93 were cut by some unknown person. The first week after the severing of the other branches close to the trunk twig 93 increased 127 mm over the previous week. Large increases were recorded each week until July 21. Total elongation was 775.0 mm, by far the greatest amount of elongation recorded by any single twig or any combination of twigs. The new bud was formed without the previous presence of a mid-summer pause.

Tilia americana

Radial enlargement began during the week ending June 17, 1947, and continued until September 22, during which time total radial enlargement of 1.58 mm was recorded. Axial increase began in area A on April 21. The peak of rate of axial increase was reached May 19 during which time the twigs averaged an increase of 48.8 mm. The mid-summer zero point was reached during the week ending June 17, no growth being recorded for the week ending June 23. Slight gains were recorded after this date. Total growth period up to the mid-summer pause for axial growth was 9 weeks. The radial growth period extended over 15 weeks with a total enlargement of 1.58 mm.

Fagus grandifolia

Radial enlargement began during the week ending May 19, 1947, and ended during the week of August 26, a total period of 15 weeks. The total radial enlargement was 1.79 mm. This is much longer than is reported by Friesner for previous years in the same trees (15). His data gives July 15 in 1941 and June 17 in 1940 as cessation dates. The remainder of the 1947 season shows only alternating losses and gains with no net increase.

Three peaks are outstanding here in relation to growth rate. The first one came during the week ending June 16 with the registering of 0.26 mm increase. The second one was June 30 with a slightly greater amount for the week (0.27 mm). The greatest peak came July 14 with a weekly increase of 0.34 mm (table I). The total radial growth period for 1947 was extended over 15 weeks.

Axial elongation began April 7 in area A. In area B the initiation time was not certain. The peak rate of axial growth was reached

the week of May 19 with an average weekly elongation of 87.2 mm. for area A. The mid-summer zero point was reached during the week ending May 26, no growth being recorded for the week ending June 4. This made a total of 8 weeks.

Rainfall charts were made of both the areas studied, and from official readings taken by the Weather Bureau. The results are presented in table III. The rainfall discrepancy is important to note both in weekly variations and in variations over a longer period of time. Temperature and evaporation data are presented in table III.

DISCUSSION

The most significant contribution of this study is the relationship between axial and radial growth. These comparative data are presented in table IV. Radial enlargement in Fagus began during the week ending May 19. This is six weeks after the inception of axial growth and comes just one week before axial growth reaches its mid-summer zero point. *Acer saccharum* was well past its peak of axial elongation when radial enlargement began during the week ending June 10. *Prunus serotina* shows radial enlargement for the first time on May 26 just one week before axial elongation had stopped. The mid-summer zero point in axial elongation was reached in *Acer platanoides* during the week ending May 26, three weeks before radial enlargement was recorded. *Tilia americana* also shows most of its axial elongation occurring before inception of radial enlargement, the axial mid-summer zero point being reached during the week ending June 17 and radial enlargement beginning during the same week. These data are shown in table IV.

It is thus rather well defined that these two types of growth are alternate. This is in agreement with Reed and MacDougal (44). They have merely indicated by straight lines the length of time of shoot growth as compared with cambial activity and root growth. In their studies shoot growth preceded cambial activity by more than one month.

The relation of time of initiation of growth with other activities of the trees agrees with results of other workers on deciduous trees (27) (14) who find the leaves from one-half to fully formed before initiating of cambial activity except in Fraxinus (27) and Quercus

(27). It is highly probable that some growth promoting substance is liberated by the reactivated meristematic region of the buds which determines at least to a certain extent the time of awakening of cambial cells.

Combined results of all dendrometer recordings (table I) showing total growth show that all five species exhibit the "grand period" type of growth. This has been previously shown for *Fagus grandifolia* and *Acer saccharum* (12) (14) but not for *Acer platanoides, Tilia americana* and *Prunus serotina. Prunus serotina* shows inception of radial enlargement well in advance of Tilia and Acer which still agrees with the work of Friesner (14) and the concept of Huber (22). Friesner's study, although not indicating in the discussion, shows that there was earlier inception of cambial activity in ring porous trees (*Quercus* and *Ulmus*) than in diffuse porous trees (*Acer* and *Fagus*). The former initiated during the week of April 21 ; the latter not until May 5 and May 12. There seems to be a definite correlation here with earlier cambial activity in relation to vegetative hud activity, at least in the semi-ring porous *Prunus serotina* as its leaves were about 1/2 to 3/4 full size when cambial activity began. Here again the situation in *Fagus grandifolia* must be taken into account and must serve as an explanation for their similar correlation. Further work will be necessary over a period of years to decide definitely on this point.

The peak of growth rate in Fagus and Prunus was also later than in the remaining three species. Time of cessation varied, but in Fagus (ceased 8-26) and Prunus (ceased 9-20) the periods were quite long. Fagus grew much longer in 1947 than was ever previously recorded on a dendrometer. Friesner reports nine weeks growth in 1940 and five weeks in 1941 ; cessations being July 15 and June 16 respectively. *Acer saccharum* on his table shows increase up to July 28. Table I gives increase in *Acer saccharum* up to August 25. During July 1947 Indiana experienced very cool weather for summer. Evaporation did not remain high at any time and rainfall was over 1 inch more than recorded in 1941. These factors would quite possibly offer an explanation for this period of extended growth since moisture was greater, evaporation was not excessive, and temperature was more nearly favorable for best growth. These factors at some time during that period influenced the rate but remained favorable

enough to extend the growing season. Axial elongation in all cases follows the "grand period" type of curve and in all cases except *A. platanoides* continues for a shorter period of time than is involved in radial enlargement. All of the species used in this study may be said to belong to the "short period" group as defined by Kienholz (23).

CONCLUSIONS

1. Total days of axial elongation in deciduous trees studied in area A were as follows: *Fagus grandifolia*: 8 weeks from April 7 to May 26; *Prunus serotina*: 8 weeks, from April 14 to June 4; *Tilia americana*: 9 weeks, from April 21 to June 17; *Acer saccharum*: 7 weeks, from April 14 to May 26; *Acer platanoides*: 8 weeks, from April 7 to May 26.

2. Total days of radial enlargement in the five species studied in area A are: *Fagus grandifolia*: 15 weeks, from May 19 to August 25; *Prunus serotina*: 19 weeks, from May 26 to September 30: *Tilia americana*: 15 weeks, from June 17 to September 22; *Acer saccharum*: 12 weeks, from June 10 to August 25; *Acer platanoides*: 8 weeks, from June 17 to August 4.

3. Total radial enlargement reached for 1947 was: *Fagus grandifolia*: 1.79 mm; *Prunus serotina*: 2.30 mm; *Tilia americana*: 1.58 mm; *Acer saccharum*: 1.46 mm; *Acer platanoides*: 1.42 mm.

4. Radial activity began in all five species after the peak of axial enlargement.

5. Axial growth exhibited after a mid-summer pause in all species studied represents very probably only bud formation since the total amount of post-mid-summer-pause-elongation never exceeds the final length of the buds measured.

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TABLE I

Dendrometer Readings of Radial Enlargement

Radial Changes Recorded by Dendrometer

Period ending	Fagus grandifolia		Prunus serotina		Tilia americana		Acer saccharum		Acer platanoides	
	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.
3-31-47	0.00	0.00	−.10	−.10					.08	.08
4-7-47	0.00	0.00	−.08	−.18					−.20	−.12
4-14-47	0.00	0.00	−.08	−.24	−.02	−.02	−.03	−.03	.01	−.11
4-21-47	0.00	0.00	.07	−.19	0.00	−.02	0.00	−.03	−.21	−.32
4-28-47	0.00	0.00	−.07	−.26	−.02	−.04	0.00	−.03	0.00	−.32
5-5-47	0.00	0.00	.04	−.22	−.02	−.04	−.01	−.04	0.00	−.32
5-12-47	0.00	0.00	−.04	0.26	0.04	−.08	−.02	−.06	−.04	−.36
5-19-47	.10	.10	.20	−.06	0.00	−.08	.01	−.05	.12	−.24
5-26-47	.08	.18	.24	.18	0.00	−.08	0.00	−.05	.03	−.21
6-4-47	.12	.30	.30	.48	0.00	−.08	.01	−.04	.11	−.10
6-10-47	.10	.40	.28	.76	.06	−.02	.03	.01	.10	0.00
6-17-47	.26	.66	.29	.85	.36	.34	.40	.39	.16	.16
6-23-47	.11	.77	.17	1.02	.16	.50	.11	.50	.15	.31
6-30-47	.27	1.04	.30	1.32	.25	.75	.22	.72	.51	.82
7-7-47	.16	1.20	.10	1.42	.19	.94	.16	.88	.14	.94
7-14-47	.34	1.54	.20	1.62	.18	1.12	.24	1.12	.10	1.08
7-21-47	.16	1.70	.10	1.72	.14	1.26	.08	1.20	.01	1.09
7-28-47	−.04	1.66	.18	1.90	.12	1.38	.16	1.36	.29	1.38

TABLE I—(Continued)

Dendrometer Readings of Radial Enlargement

Radial Changes Recorded by Dendrometer

Period ending	Fagus grandifolia		Prunus serotina		Tilia americana		Acer saccharum		Acer platanoides	
	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.
8-4-47	.11	1.77	.08	1.98	.06	1.44	.04	1.40	.04	1.42
8-11-47	–.11	1.66	0.00	1.98	0.00	1.44	–.02	1.38	–.05	1.37
8-18-47	.11	1.77	.12	2.10	.05	1.49	.02	1.40	.01	1.38
8-25-47	.02	1.79	.08	2.18	.01	1.50	.06	1.46	0.00	1.38
9-1-47	0.00	1.79	.08	2.26	.02	1.52	–.02	1.44	0.00	1.38
9-8-47	–.06	1.73	–.01	2.25	–.01	1.51	0.00	1.44	–.01	1.37
9-15-47	0.00	1.73	.01	2.26	.05	1.56	–.08	1.36	0.00	1.37
9-22-47	0.00	1.73	.02	2.28	.02	1.58	0.00	1.36	0.00	1.37
9-30-47	.02	1.75	.02	2.30	0.00	1.58	0.00	1.36	–.05	1.32
10-6-47	–.10	1.65	–.08	2.22	–.04	1.54	–.06	1.30	–.02	1.30
10-13-47	–.02	1.63	–.04	2.18	.02	1.56	–.02	1.28	–.04	1.26
10-20-47	.08	1.71	0.00	2.18	0.00	1.56	0.00	1.28		
10-27-47			.06	2.24	–.02	1.54	.02	1.30		
11-3-47	.02	1.73	–.07	2.17	.02	1.56	.02	1.32		
11-10-47	0.00	1.73	.06	2.23	0.00	1.56	–.02	1.30		
11-17-47	–.06	1.67	–.02	2.21	0.00	1.56	–.04	1.26		
11-24-47	.01	1.68	.02	2.23	0.00	1.56	–.02	1.24		
12-1-47	–.22	1.46	0.00	2.23	–.34	1.22	–.05	1.19		
12-8-47	.18	1.64								
12-15-47	–.12	1.52							–.14	
12-22-47	–.03	1.49	–.04	2.19	–.08	1.14	–.04	1.15	–.03	
12-29-47			.02	2.21	.02	1.16	–.01	1.14	–.05	
1-5-48	.15	1.64	0.00	2.21	.02	1.18	.04	1.18	.06	
1-22-48	–.86	.78	–.34	1.87	.24	1.42	–.18	1.00	–.40	
1-29-48	–.24	.54	–.22	1.65	–.44	.98	–.04	.96	–.21	
2-3-48			.42	2.07			.08	1.04	.41	
2-16-48	.92	1.46	.21	2.28	.24	1.22	.11	1.15	.08	
2-23-48	–.02	1.44	.01	2.29	–.20	1.02	–.01	1.14	–.26	
3-1-48	.14	1.58	0.00	2.29	0.00	1.02	.01	1.15	.24	
3-8-48	0.00	1.58	–.01	2.28	–.03	.99	.01	1.16	.02	
3-15-48	–.04	1.54	.02	2.30	.13	1.12	–.06	1.10	–.02	
3-24-48			–.06	2.24	–.10	1.02	.02	1.12	–.06	
3-29-48	.04	1.58	0.00	2.24	–.10	.92	.04	1.16	–.04	
4-5-48	.01	1.57	0.00	2.24	–.10	.82	–.02	1.14	–.04	
4-12-48	.02	1.59	.03	2.27	–.04	.78	.02	1.16	.04	
4-19-48	–.04	1.55	–.01	2.26	–.08	.70	–.02	1.14	–.04	
4-26-48	0.00	1.55	.02	2.28	–.08	.62	.00	1.14	–.04	

TABLE II

Axial Elongation

	Prunus		Fagus		Acer saccharum		Tilia	Acer platanoides
Date	Area A	Area B	Area A	Area B	Area A	Area B	Area A	Area A
4-7-47	0 mm		0.06 mm		0 mm		0 mm	1.7 mm
4-14-47	5.6		1.3	1.2 mm	2.2	1.0 mm	0	4.9
4-21-47			1.7	4.9	1.0	3.7	0.37	9.0
4-28-47	15.2	1.49 mm	4.4	5.9	3.0	6.2	1.85	
5-5-47	25.7	24.6	12.9	18.6	15.1	16.8	6.3	9.8
5-12-47	15.4	21.8						2.6
5-19-47	16.8	33.8	87.2	7.9	104.9	10.3	48.8	7.1
5-26-47	9.8	40.0	2.9	0.7	47.2	0.3	18.9	1.0
6-4-47	2.3	15.3	0	1.1	20.5	0	7.9	0
6-10-47	0	15.7	0	0.3		0	0.3	0
6-17-47	0.2	18.0	0	0.4		1.3	2.0	0.76
6-23-47	0	4.3	0	0		0	0	0.26
7-7-47	0	5.7	1.7	1.2		1.2	0	1.3
7-21-47	0	0.3	0.2	0.8		0.4	0.7	0.41
9-1-47	1.0	0.4	4.1	3.9		1.1	0	0.9
	92.0	181.99	116.4				85.22	53

TABLE III

Rainfall, Evaporation and Temperature.

Week ending	Rainfall				Evaporation	Temperature—Averages		
	Area A	Area B	Airport	Holliday		Maximum	Minimum	Mean.
4-1-47			.20 in.	.07 in.		47°F.	29°F.	38°F.
4-8-47			.89	.99	.119 in.	59	41	50
4-15-47			1.64	1.52	.101	62	39	50.5
4-21-47			.75	1.02	.123	48	32	40
4-28-47	1.45 in.	1.40 in.	1.56	1.45	.117	64	40	52
5-5-47	1.15	1.10	1.05	1.17	.101	61	47	54
5-12-47	.24	.31	.28	.21	.129	66	37	51.5
5-19-47	1.41	1.85	1.71	2.05	.184	76	56	66
5-26-47	1.57	1.30	.93	1.39	.153	72	51	61.5
6-4-47	3.40	2.38	2.31	3.09	.118	72	49	60.5
6-9-47	.86	1.66	2.95	.60	.137	81	63	72
6-17-47	.39	.36	.45	.27	.187	72	56	64
6-23-47	.35	.53	.40	.27	.155	74	58	66
6-30-47	.13	.40	.28	.41	.133	81	64	72.5
7-7-47	.07	.15	.03	.00	.193	71	59	65
7-14-47	1.49	.55	.84	1.03	.169	82	62	72
7-21-47	.50	.23	.33	1.12	.133	79	69	74
7-28-47	.18	1.23	1.13	.08	.180	81	58	69.5
8-4-47	.68	.68	1.00	1.55	.221	88	64	76
8-11-47	.07	.12	.04	.23	.202	91	68	78.5
8-18-47	2.77	2.77	2.79	2.88	.150	89	73	81
8-25-47	.07	.22	1.37	.08	.157	92	72	82
9-1-47	.43	.36	.02	1.01	.105	87	68	77.5
9-8-47	.38	.52	.53	.28	.133	87	65	76
9-15-47	1.10	1.45	1.58	1.14	.139	81	63	72
9-22-47	1.25	1.42	1.32	1.32	.135	79	54	66.5
9-29-47	.02	.03	.02	.00	.105	66	42	54
10-6-47	.12	.44	.58	.19	.092	70	45	57.5
10-13-47	.00	.00	.00	.00	.085	77	52	64.5
10-20-47	1.20	1.50	.38	1.10	.073	78	54	66
10-27-47	.94	1.75	1.19	.89	.076	77	52	64.5
11-3-47	.51	.60	.42	.57		72	45	58.5

TABLE IV

Correlation between axial elongation and radial enlargement.

	Axial Elongation			Radial Enlargement		
Species	Period	Weeks	Amount (Average)	Period	Weeks	Amount
Prunus	Apr. 14-Juue 4	8	92 mm	May 26-Sept. 30	19	2.30 mm
A. platanoides	Apr. 7-May 26	8	39.7	June 17-Aug. 4	8	1.42
A. saccharum	Apr. 14-May 26	7	42.3	June 10-Aug. 25	12	1.46
Tilia	Apr. 21-June 17	9	48.8	June 17-Sept. 22	15	1.58
Fagus	Apr. 7-May 26	8	87.2	May 19-Aug. 25	15	1.79